EFFECT OF FOOD STIMULATING AGENTS ON FLEXURAL STRENGTH ON DENTURE BASE RESINS – AN IN VITRO STUDY

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At last, I thank the **Almighty** for blessing me throughout this period.

INTRODUCTION

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Dental restorations can degrade and age due to the existence of saliva; food components, beverages and interactions among the materials in oral environment [39]. It has been observed that when dental restorations are exposed to food components and beverages in the oral environment, there is a change in the physical and mechanical properties of denture base resin. Heat cure resin removable dentures on a long term use are susceptible to fracture due to various factors such as masticatory forces which induces stress distribution in the denture base[3]. Due to the mechanism of liquid absorption and adsorption these changes are seen in the heat cure denture base[4,5]. Thus, it is evident that the solvents present in the food components can soften the polymeric dental materials due to its chemical interaction with the denture base resins[6].

The acrylic resins when exposed to the chemical agents constantly, there is formation of adherent debris around the restorations which has deleterious effects on the properties of denture base resins[7,8]. The degradation and aging on denture base resins occur due to the action of food stimulating agents such as ethanol, citric acid, heptanes and lactic acid. They are also known as food simulators. These food simulators are ethanol, citric acid, heptane, distilled water and lactic acid. Ethanol causes irreversible degradation by penetrating the matrix and expanding the space between the polymer chains in poly methyl methacrylate and enhances the plasticization of crack formation in denture base resin [9,10] ;Water is a complex solvent and because of its strong interaction with polymer, it forms hydrogen bonds during its action with resin and Citric acids too affect the properties of denture base resins by causing hydrolysis on the resin matrix.

Studies suggest that there is a change in the mechanical properties such as flexural strength and hardness of the denture base resins by ethanol but its varying concentrations are not known. Thus, the aim of this study is to evaluate the flexural strength of denture base resins in three different concentrations of ethanol (20%, 40% and 50%) and citric acid (0.02N).

AIM AND OBJECTIVES

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The study is done to investigate the interaction of food stimulating agents such as citric acid (0.02N) and ethanol in concentrations (20%, 40% & 50%) on denture base resins to find out the variations in flexural strength.

OBJECTIVES:

1. To determine the variation in flexural strength between food stimulating agents and denture base resin with the water, after conditioning it for a week at room temperature.

2. To determine the variation in flexural strength between food stimulating agents and denture base resin with 20% ethanol after conditioning it for a week at room temperature.

3. To determine the variation in flexural strength between food stimulating agents and denture base resin with 40% ethanol after conditioning it for a week at room temperature.

4. To determine the variation in flexural strength between food stimulating agents and denture base resin with 50 % ethanol after conditioning it for a week at room temperature.

4. To determine the variation in flexural strength between food stimulating agents and denture base resin with 0.02N citric acid after conditioning it for a week at room temperature

5. To evaluate the flexural strength of denture base resins by conditioning specific food stimulating agents such as ethanol (20%, 40% & 50%) and citric acid (0.02N) .

REVIEW OF LITERATURE

REVIEW OF LITERATURE

A study to determine the amount of residual monomer in poly methyl methacrylate by gas chromatography by *Douglas (1978)*[17]. The gas chromatography technique had revealed that the unreacted monomer content cause plasticizing effect which decreases the bond between the polymer matrix. Later on, he concluded that this unreacted monomer was the most important reason to decrease the mechanical properties of denture base resins. In spite of all these negative factors, PMMA has considered to be a good biocompatible material to oral tissues.

A study by *Solderhom (1982)*[18]did to analyze the relationship between the compressive yield strength and filler content in PMMA composites. By adding filler content in composite resin the strength of the material has increased when it reached the proper volume. Thus, this study reveals the way to in in-vivo conditions, to increase the longevity of the materials by increase in ratio of filler content along with its volume which in turn improves the strength.

In a review article by *Bowen (1982)*[19]did a research on the polymerization shrinkage of various restorative resins when it is placed in water. The restorative materials showed hygroscopic expansion to compensate the polymerization shrinkage. Thus, shrinkage compromises longevity of the restorative material along with changes in mechanical properties of the material.

Asmussen (1984)[8], did a study on the softening of BISGMA polymers by ethanol and organic acids. The inference in this study is that certain organic acids obtained from plaque may induce a softening of BISGMA – based polymers, due to the content of TEGDMA. Organic acids such as acetic acid and propionic acid may

influence the quality of resinous restorations with respect to wear and surface staining. On further observation it has been evaluated that the high extent of polymerization is desirable if monomer content is low in TEGDMA; a chance for formation of marginal gaps with increase in polymerization and internal discoloration if the content is high in TEGDMA .

In-vivo study showed changes on surface dissolution of matrix in Glass Ionomer and in Composites due to exposure in oral fluids were accessed by *Roulet et al (1984)*[9] in this the exposed filler particles were observed with the help of Scanning Electron Microsocpe (SEM). Hence proved that the silane coating of the filler and resin is not stable under oral conditions. Therefore the manufacturers should be encouraged to improve the bond between the filler and matrix in composite resins as it showed decrease in flexural strength when exposed to food components in oral fluid.

The study based on the influence of chemical food stimulating liquids on the wear of dental composite restorations by *Mc Kinney and Wu W (1985)*[7] where the degradation has been taken place mostly by ethanol of 75% and unmarked change has happened in heptane. The wear behavior was considerably high when compared with that of other materials. The result of this work suggests that certain possible improvements in composite restorations which increases the durability of the material. *Oysaed H, Ruyter (1986)*[20], did a study in composites by using it in posterior teeth where mechanical properties were tested under dry and wet conditions. They have exhibited lack of oxygen inhibition layer on the surface due to its low number of unreacted monomers on the surface which is subsequent to polymerization. Incidentally, it was observed that organic solvent promotes the release of unreacted

monomers and inorganic fillers in the resin matrix due to its action in filler and resin matrix.

The study on effect of water was analyzed by *Calais (1988)*[21]in which he inferred about the effect on the filler type and on the flexural strength of composite resins .The results indicated that the water has detrimental effect on the strength of the matrix than on the filler-matrix interface. However, there was relatively a high frequency of fracture lines in the porous silica particles after storage in water which shows that water had a weakening effect on the filler especially in TEGMA.

In vivo-study by *Kao(1989)*[22]had a specific aim on this study to determine the effect of food stimulating solvents (heptane and ethanol) on varying resin composites and glass ionomer. Multifactorial analysis of variance revealed that there was a significant difference in hardness (using Knoop hardness tests) due to the surface finish of the restorations, concentration and storage time of food stimulating solvents. The change has been observed in flexural strength and hardness of the restoration due to surface finish. In specific, urethane DMA matrix were found to be significantly more susceptible one among other matrices due to its difference in bond between filler and matrix which sub sequentially subjects it to dehydration.

A study to compare the interaction of water and artificial saliva on the mechanical properties of denture base materials by *Mulla et al (1989)*[23]. The properties of the selected artificial samples has to satisfy the properties of natural saliva and water. In general, the mechanical properties were similarly affected in all liquids whereas diffusion coefficient alone differs. Thus, this study shows that the artificial saliva also has similar effects on denture base materials by showing some changes in its mechanical properties.

Solderholm(1990)[24] did a study to analyze the influence of water exposure on tensile strength of composites. They evaluated that the water has detrimental effects on composites. The action of water is to destroy the filler-matrix bonds which results in irreversible reduction in tensile strength and plasticizing effect accompanied by swelling in surrounding matrix, thus reduces the stresses around the filler particles.

Caycik (1992)[25]studied on the effect of cross linking chain length on mechanical properties on a PMMA resin. In this, they have compared three different cross-linking agents of varying concentrations which were added to the monomer component in the resin and their effects on the mechanical properties on cured polymer were investigated. Finally, they showed that there was an increase in properties like Flexural strength and impact strength due to the increase in chain lengths of cross-linking agents with decrease in transverse bend strength and tensile strength. This study showed after improving the strength the material, in-vivo conditions due to the action of food stimulating agents it caused changes in the properties of the material.

Harrison (1993)[26]did a study were they have compared the dimensional accuracy of microwave and conventionally polymerized denture base materials. Dimensional stability is the degree -to which the dimensions of a denture base alter with the time after polymerization. So, when comparing the dimensional accuracy they found that the amount of residual monomer was less for the conventional curing method (0.55%) and more for microwave system. So, conventional method of fabricating denture base is considered to be the favorable one due to less residual monomer when compared with other methods.

On further analysis by *Yunus (1994)*[27]inferred that the flexural strength and residual monomer of an acrylic resin repair material with the help of microwave irradiation. The degree of polymerization of an acrylic resin repair material was established by evaluating the residual monomer content which was compared with three different polymerization methods such as bench cure, hydro-flask cure and microwave irradiation cure. In this, they have identified that the residual monomer has an effect on strength of the repaired specimens. On further research they have stated that the highest level of residual monomer decreases the strength of the material. In oral conditions, due to this release of residual monomer and with the action of food stimulating agents it can easily deteriorate the strength of the material. So, the release of residual monomer has to be reduced during the polymerization procedure.

A study to detect the leached moieties from dental composites in fluid stimulating food and saliva *by Lee (1995)*[28] in which he analyzed that the Infrared spectroscopy of a liquid stimulating food and saliva when exposed to resin composites with Fourier Transform Infra red Spectroscopy (FTIR). On further observation, he analyzed that the ethanol shows variation in band and considered as an irreversible process with leaching out of components from the material. To conclude, this phenomenon may contribute to irreversible material degradation.

Dogan (1995)[29]studied on the curing cycle of denture base resins. This study states that the level of residual monomer decreases with the increase in curing time. At the same time, the tensile strength was improved and water absorption was decreased. If the residual monomer exists in higher ratio it causes plasticizing effect on the resin by decreasing the bonding between polymer and matrix, which sub sequentially decreases the hardness as well as the strength of the material. Thus, in

oral environment due to the action of certain food contents especially such as ethanol due to its corrosive action it decreased the strength of the material.

A study on the Fourier transform Infra-red emission spectroscopy to analyze the polymer degradation by *Celina (1997)*[30], in which they gave detailed explanation regarding the degradation of PMMA. Thus, degradation of PMMA occurs due to the release of volatile components when it reaches beyond the higher ceiling temperature of 155 ^{0} C. On further analysis there was an expected loss of material from the polymer when it reaches the Ceiling temperature of 250 ^{0}C which was recorded in FTIR spectrum. After a certain period of time, the material has almost completely disappeared with decrease in all bands of the spectrum. Therefore, the material basically shows variation in band during the degradation. Finally, it is concluded that this study has evaluated the variation of bond in PMMA clearly by Fourier Transform Infra-red Emission Spectroscopy.

Ruyter (1998) [31] did a study based on the effect of polymerization temperature and time on the residual monomer content of denture base polymers. In order to identify the content of residual monomer in the denture base resin which was observed with the help of gas chromatography. The release of monomer is reduced due to the action of tertiary amine in long curing cycle. Eventually, it shows the residual monomer release is less in long curing cycle than short curing cycle. The release of monomer and it action in oral environment along with the food stimulating agents eventually decreased the strength of the material.

A study on the microwave polymerization of denture base materials which showed that degree of conversion of resin mainly depend on the dimethacrylates by *Blagojevic V, Murphy V (1999)*[32] in which increase the final degree of conversion of

resin can be improved by increasing the distance between dimethacrylates. The final degree of conversion of a resin also depends on the polymerization conditions such as atmosphere, temperature, light intensity and photo initiator concentration. Thus based on these concerned factors, the strength of the material evaluated after its interaction with food stimulating agents.

A study to evaluate the effect of water sorption on the flexural strength on a relined denture base resins by *Takahashi (1999)*[33]. Thus, the water sorption is high in relined material which in turn increases the size of the matrix but it eventually decreases the flexural strength. It proves that water sorption changes the intrinsic strength of the denture base resins.

Chai (1999)[34] did a study to characterize the effect of water immersion on the strength of denture polymers. Four each of the denture base polymers and denture reline materials were tested for flexural strength at long intervals. The water immersion has affected the strength of the most denture polymers due to its change in bond in the resin matrix. Each denture polymer behaved differently in response to water immersion.

In-vivo study by *Archadian (2000)*[35] did a research on identifying the flexural strength of rebased denture polymers in oral conditions. They have clearly analyzed that there was a decrease in residual monomer during polymerization, it occurred mainly due to the presence of radicals in resin matrix , where acrylic is converted to polar material due to diffusion by water. These absorbed water molecules breaks down the bond chains in denture base resin with increase in action of plasticizer by forming a long chain polymers. Finally, it decreases the chemical properties of the denture base resins.

A study to evaluate the effect of water sorption on the flexural strength on a relined denture base resins by *Yap (2001)*[12]. In this study, the specimens were conditioned for a week in artificial saliva, distilled water, Citric acid, Lactic acid, heptane and 75-25% ethanol – water solution. Finally, the inference was both organic solvents and water/ weak acids may degrade the composite resins. The effect of chemical media changes its surface hardness and increases the thickness on degradation layer. Thus, all the composites are preferably softened by 75-25% ethanol and they shows that the thicker degradation layer which is associated with greater softening of composite

The study based on action of food simulators based on shear strength of composites done by *Lee (2002)*[2]. There was significant change in shear strength, when it is conditioned with heptane, ethanol and citric acid. The heptane increases shear strength whereas ethanol and citric acid decreases the shear strength. In this study they have identified that the flexural strength is the most commonly affected and is also decreases along with shear strength of the material.

A study on the dietary solvents by *Yap(2004)*[10] to verify the hardness of provisional restorative materials with the surface of chemical , light and dual-cure provisional restorative materials. In comparison with all the other dietary solvents, Ethanol has a significant change in a concentration of 25% with a compromised functional longevity of the restorative materials. The inference observed is Bis-acryl composite material which contains bifunctional acrylates that cross links to provide increased mechanical strength and resistance, whereas methyl methacrylate based materials does not have the benefit of cross-linked bifunctional acrylates and consequently have a reduced resistance to the softening effects of dietary stimulating solvents.

In this clinical study, *Akova(2006)*[13], conducted a study based on the mechanical properties of provisional restorative materials by the use of food simulating agents. Thus, the flexural strength of the provisional materials is crucial due to its action with food simulating agents. It has proved that action of alcohol compromises the functional longevity of these restorations whereas water tends to cause weakness in filler-matrix debonding; weak intra oral acids such as citric acid and lactic acid decreases the flexural strength by its action on inorganic fillers.

Ahmed et al (2011[36], did a study on aluminium oxide / zirconium oxide reinforcement to increase the mechanical properties of PMMA denture base. Thus, by adding aluminium oxide / zirconium oxide at a ratio 80:20 which shows the highest value of fracture toughness and flexural properties? By using Scanning Electron Microscopy (SEM), they have ruled out that these two materials (aluminium oxide and zirconium oxide) make the PMMA matrix fairly homogenous and finally it increases the mechanical properties by the change in interface between the reinforcement particles. The enhanced PMMA in oral conditions showed improved properties in the denture base resins.

Sodagar (2013)[37]did a study to identify the incorporation of nanoparticles such as titanium oxide and silicon-di- oxide which has an effect on flexural strength of denture base materials. Thus, by incorporating these nano particles the bond in resin matrix is significantly affected and also compromises the flexural strength. This shows that it is mainly based on the concentration of nano particles enhances properties in in-vivo conditions but further analysis has to be proceeded in detail.

An in-vitro study by *Koray Soygun (2013)*[38]did an in-vitro study to investigate the mechanical and thermal characteristics of denture base resins by incorporating fibers.

The results showed that by adding these fibers as fillers in the denture base resins it increases the strength of the denture base resins. This has to be analyzed in the in-vivo study to evaluate the property.

Rajaee (2014)[39]did a study on the food stimulating agents and identified the variation in flexural strength of denture base resins. In this study, he has evaluated that the ethanol and citric acid has destructive mechanism on denture base resins by undergoing changes in the resin matrix. These changes in resin matrix affects the flexural strength of the denture base resins and consequently decrease the mechanical properties of the denture base resins.

An in-vitro study based on the effect of food stimulating agents on hardness and bond strength of a silicone soft liner to a denture base acrylic resin by *Khaledi et al (2015)*[40] where they analyzed that the bond strength showed changes in the soft liner and denture base acrylic resin. Thus, water, 50% ethanol, hepatne and citric acid showed changes in the property of the material.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present laboratory study was carried out to determine and evaluate the effect of food stimulating agents on denture base resins based on their flexural strength.

Table 1: Materials

S No	**Procedure**	**Material**	**Brand, manufacture**
1	Denture base resin samples	Heat cured poly methyl methacrylate resin(PMMA)	ACRYPOL R, Ruthinium group, Dental manufacturing S.p.a, Italy
2	Food stimulating agents	20% ethanol	Ethanol (99.9%), Changshu Hongsheng Fine chemical Co. Ltd, China.
		40 % ethanol	Ethanol (99.9%), Changshu Hongsheng Fine chemical Co. Ltd, China.
		50% ethanol	Ethanol (99.9%), Changshu Hongsheng Fine chemical Co. Ltd, China.
		Citric acid	Citric acid (99.5%) anhydrous, Changshu Hongsheng Fine chemical Co. Ltd,China.

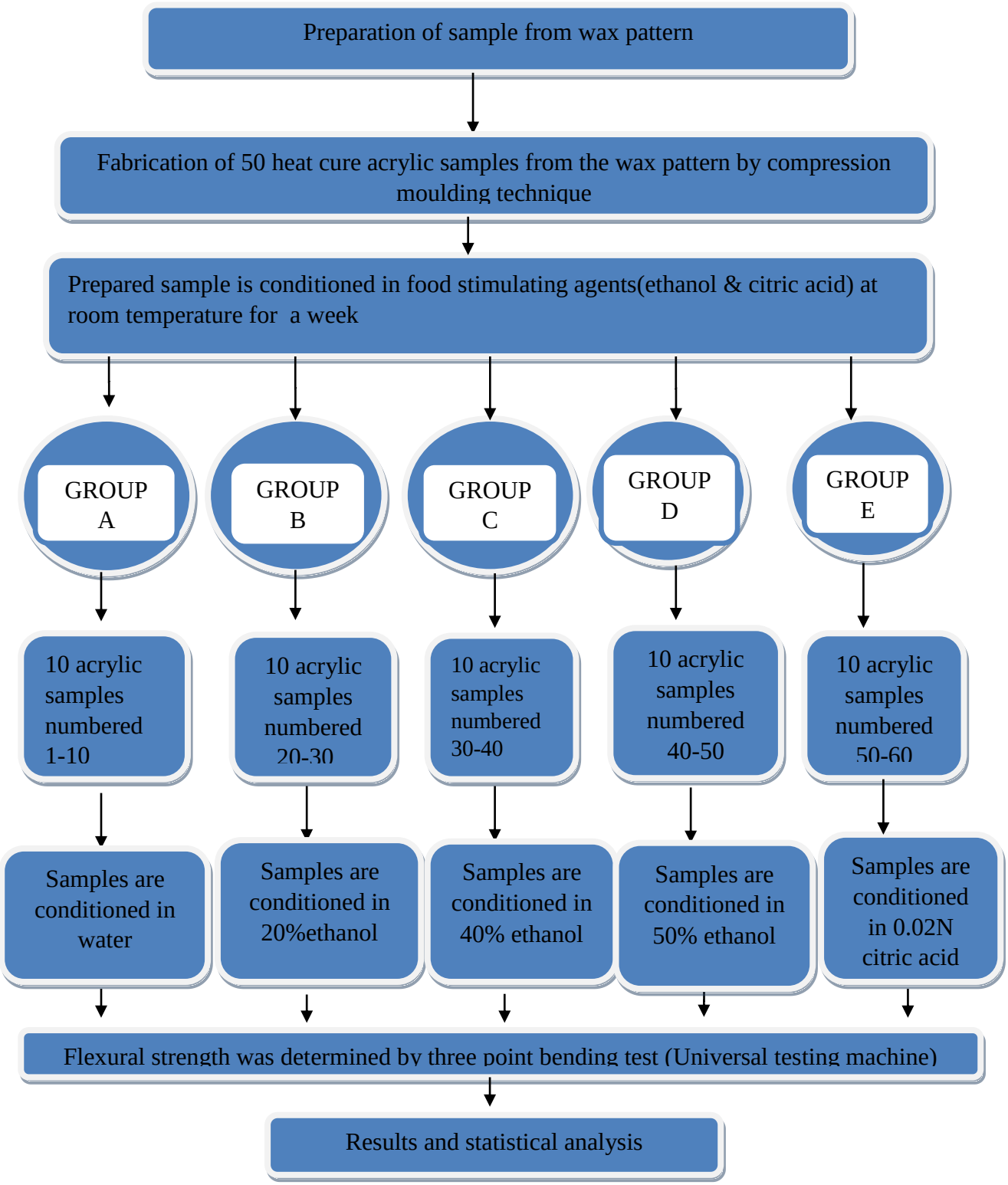
Table 2: Equipment

S NO	Procedure	Instrument	Brand , manufacture
1	Measurement of flexural strength	Universal testing machine	UTI (universal testing machine) Zwick Rowell, Germany.

METHODOLOGY

In this study, by compression molding technique the acrylic samples are fabricated with the help of wax pattern in a determined size and shape.

STUDY DESIGN:



FABRICATION FOR THE ACYLIC SAMPLE :

The acrylic samples(ACRYPOL) were fabricated by compression moulding technique from the determined wax pattern according to the following dimensions based on American Standard Test Methods (ASTM) (diagram1,figure1) with the dimensions of 60(length)*12(breadth)*3(thickness)mm .

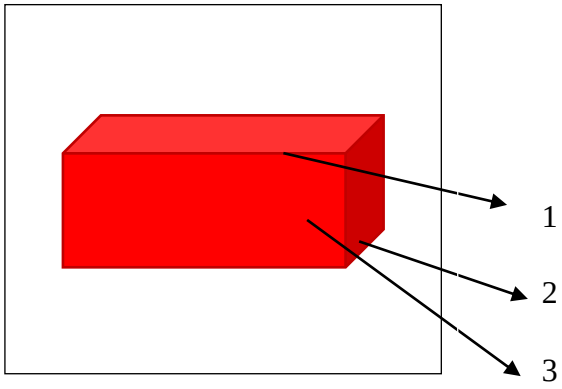


Figure 1.3 D image of wax sample

1. Length of the wax die – 60 mm
2. Breadth of the wax die – 12 mm
3. Thickness of the wax die – 3mm

FABRICATION OF THE SPECIMENS:

50 Heat cure acrylic samples were fabricated from the wax pattern after it has been obtained in the determined shape and size (Fig 1) . The samples were fabricated through compression moulding and packing was done with the help of ACRYPOL heat cure material, followed by short curing cycle (73^0 C for 90 minutes and 100^0 C for 30 minutes). The specimens were divided into 4 groups with 10 in each for conditioning that specimens.

PREPARATION OF SOLUTION FOR CONDITIONING THE SAMPLE:

The ethanol and citric acid has to be diluted to the estimated percentage of 20% , 40 % and 50% in concentrations and 0.02N of citric acid by the following dilution methods to condition these acrylic samples.

DILUTION METHOD :

Group B:

Available concentration (N1) = 99.9%

Required concentration (N2) = 20%

Volume to be pipette out (V1) = x ml

Required volume (V2) = 100 ml.

Based on the formula of Normality,

$$V1N1 = V2N2$$

$$V1 = \frac{V2N2}{N1}$$

$$V1 = 20 \times 100 / 99 = 20.2ml$$

Thus, by using 20 ml of 99.9% ethanol was diluted with 80 ml of distilled water which gives 20 % concentrated ethanol.

$$20\ \%\ \text{concentrated ethanol} = \frac{20}{100} \times 100 + 80\ \text{ml of water}$$

where we obtained estimated 20 % concentrated ethanol for conditioning the sample.

Group C:

Available concentration (N1) = 99.9%

Required concentration (N2) = 40%

Volume to be pipette out (V1) = x ml

Required volume (V2) = 100 ml.

Based on the formula of Normality,

$$V1N1 = V2N2$$

$$V1 = \frac{V2N2}{N1}$$

$$V1 = 40 \times 100 / 99 = 40.2\text{ml}$$

Thus, by using 40 ml of 99.9% ethanol has to be diluted with 60 ml of distilled water which gives 40 % concentrated ethanol.

$$40\ \%\ \text{concentrated ethanol} = \frac{40}{100} \times 100 + 60\ \text{ml of water}$$

where we obtained estimated 40 % concentrated ethanol for conditioning the sample.

Group D:

Available concentration (N1) = 99.9%

Required concentration (N2) = 50%

Volume to be pipette out (V1) = x ml

Required volume (V2) = 100 ml.

Based on the formula of Normality,

$$V1N1 = V2N2$$

$$V1 = \frac{V2N2}{N1}$$

$$V1 = 50 \times 100 / 99 = 50.2ml$$

Thus, by using 50ml of 99.9% ethanol has to be diluted with 50 ml of distilled water which gives 50% ethanol

$$50\ \%\ \text{concentrated ethanol} = \frac{50}{100} \times 100 + 50\ \text{ml of water}$$

where we obtained estimated 50 % concentrated ethanol for conditioning the sample.

Group E:

In citric acid, the weight of the substance has to be calculated for diluting it.

To calculate the weight of the substance:

Equivalent weight of citric acid = 64g.

$$\text{Normality} = \frac{\text{weight of the substance} \times \text{Volume in litre}}{\text{Equivalent weight of citric acid}}$$

$$0.02\ N = \frac{x}{64x\ 100/1000}$$

$$X = \frac{0.02 \times 64x1000}{100} = 0.128g.$$

Thus by using 0.128 g of citric acid dissolved in 100 ml of distilled water to obtain the estimated 0.02 N citric acid for conditioning the sample.

Thus, after diluting the solutions it has to be conditioned with the samples for 7 days

GROUP A: Consisted of 10 samples numbered from 1-10 and to condition the sample with water

GROUP B: Consisted of 10 samples numbered from 10-20 and to condition the sample with 40% ethanol.

GROUP C: Consisted of 10 samples numbered from 20-30 and to condition the sample with 50 % ethanol.

GROUP D: Consisted of 10 samples numbered from 30-40 and to condition the sample with 0.02N citric acid

The acrylized samples were trimmed, finished and polished before conditioning it with food stimulators. Before determining the flexural strength, they are conditioned with food stimulating agents (ethanol-20%, 40%& 50% and citric acid-0.02N) for a week at a room temperature. 24 hour storage simulate one month of consistent drinking. Thus, 7 days of conditioning takes 7 months of drinking period. Hence, to

simulate 7 months beverage consumption, we immersed the dentures in their respective solutions for a period of 7 days. Within 7 days of conditioning with these solutions, there was a significant change in flexural strength of denture base resins. As, this period seemed to be long but the interaction with the food simulators can attach around the margins of the restoration or teeth present on the denture or in the porosities of denture which act as a reservoir for intermittent or continuous action of simulating agents on the denture base resins. So, a minimum period of 7 days conditioning period had been applied in this study.

After the conditioned period, the sample was washed with running tap water and dried and flexural strength was analyzed.

ANALYSIS OF SPECIMEN:

The further analysis of the conditioned specimen was carried out with the help of the universal testing machine i.e., three point bending test where flexural strength has to be measured to analyze the effect of the ethanol and citric acid on the denture base resin

FLEXURAL STRENGTH:

The flexural strength is defined as "force *per unit area at the instant of fracture in attest specimen subjected to flexural loading".*

It is al so known as modulus of rupture. The flexural strength can be measured by three point or four point bending test.

TESTING THE SAMPLE:

Three point bending test:

The flexural strength was performed according to ISO standard 1567:1999. It is a measure of how a material behaves when under multiple stresses. It is measured by subjecting a beam of the material to three- or four-point loading which results

in the development of compressive stresses on the top of the beam, tensile stresses on the bottom, and shear stresses on the sides. The test is very sensitive to the specimen, specifically on the tensile stress surface. A high flexural strength is desired once these materials are under the action of chewing stress that might induce permanent deformation.

In the universal testing machine, the specimens were subjected to three-point bending test. The specimens were supported at the centre of the support span and width and the depth of the specimens were measured. The long axis of the specimens is perpendicular to the loading nose. The specimen was subjected to the load at a specified crosshead rate and the data of the load deflection was recorded simultaneously.

All the samples were subjected to three point bending test. The measurement of the samples were done by moving the samples to maximum distance on applied load.

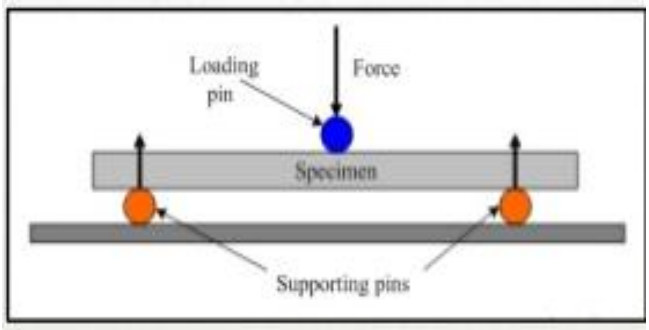


Fig 2: Working mechanism of universal testing machine

For calculating the flexural strength, following formula was used :

Flexural strength $=3PL/2bd^2$

Stress= $2bd^2$, where P=Applied load; L=Support span (mm); b=Width of beam (mm); d= depth (mm).

The flexural strength has been obtained based on the stress- strain formula by applying constant load at a determined speed. The difference of mean values of the groups were tested by using ANOVA test and Post-hoc analysis. P-value is less than 0.05% .

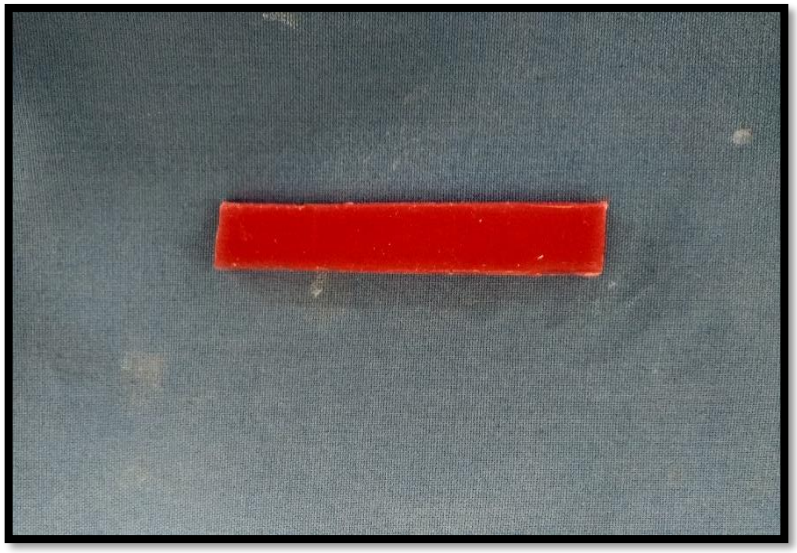


Fig 3: Wax sample of determined dimensions

Fig 4: ACRYPOL- Heat cure resin used in this study

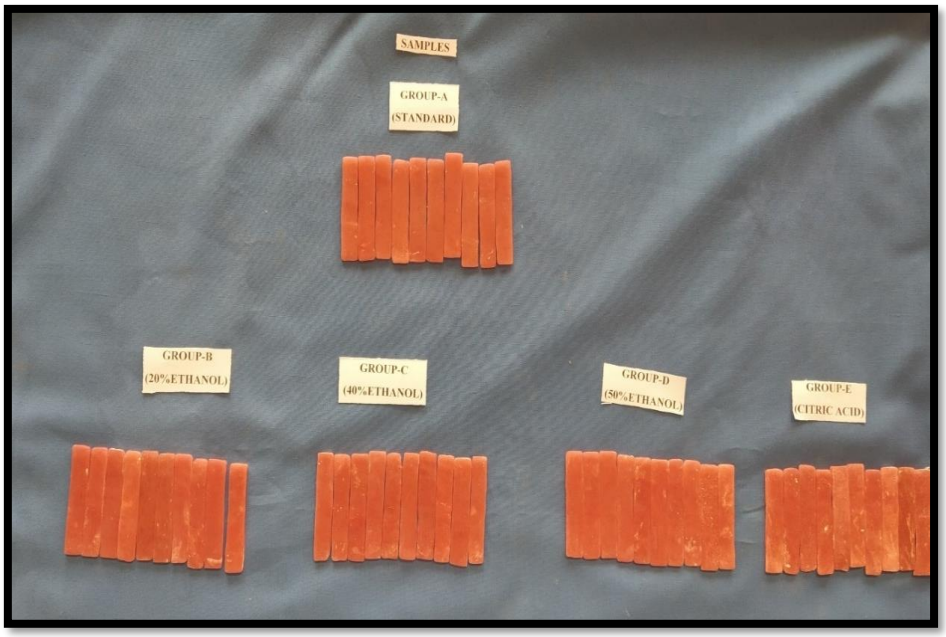


Fig 5: Fabricated test sample in acrylic resin

Fig 6 : group A (control group)

Fig 7 : Group B (to be conditioned with 20% ethanol)

Fig 8 : Group C (to be conditioned with 40% etahnol)

Fig 9 : Group D (to be conditioned with 50 % ethanol)

Fig 10 : Group E (to be conditioned with citric acid)

Fig 11 : Ethanol (99.9%-pure form)

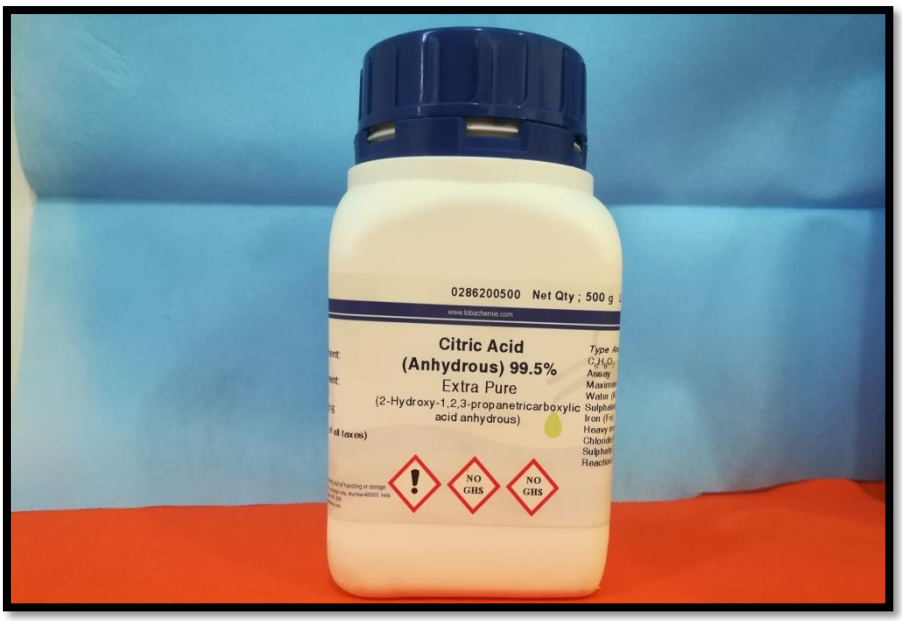


Fig 12 : Citric acid (99.5% anhydrous)

Fig 13 : Individual bekaers for conditioning the samples(standard, 20% ethanol,40% ethanol & 0.02N citric acid).

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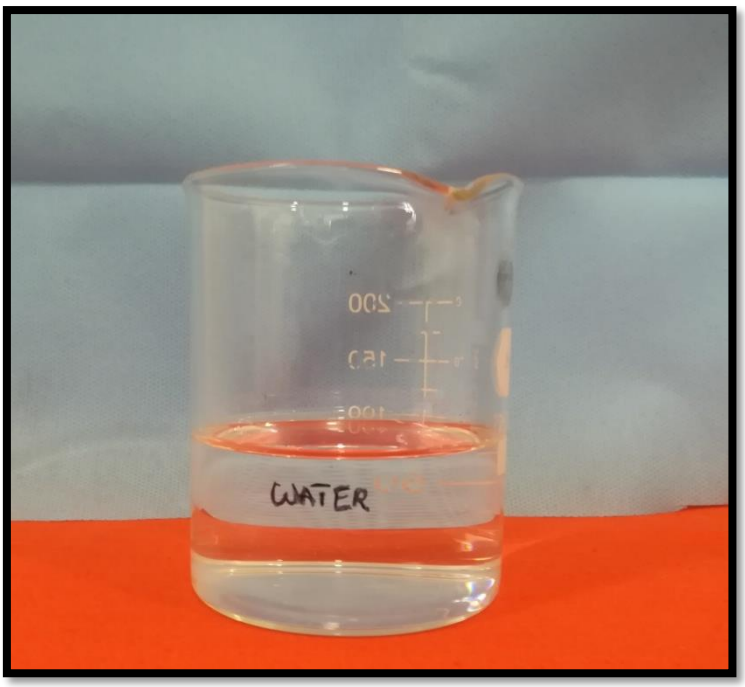


Fig 14: Water for conditioning the sample in a beaker (Group A –standard)

Fig 15: After diluting the 99.9% ethanol to 20% concentration in an individual beaker as Group B

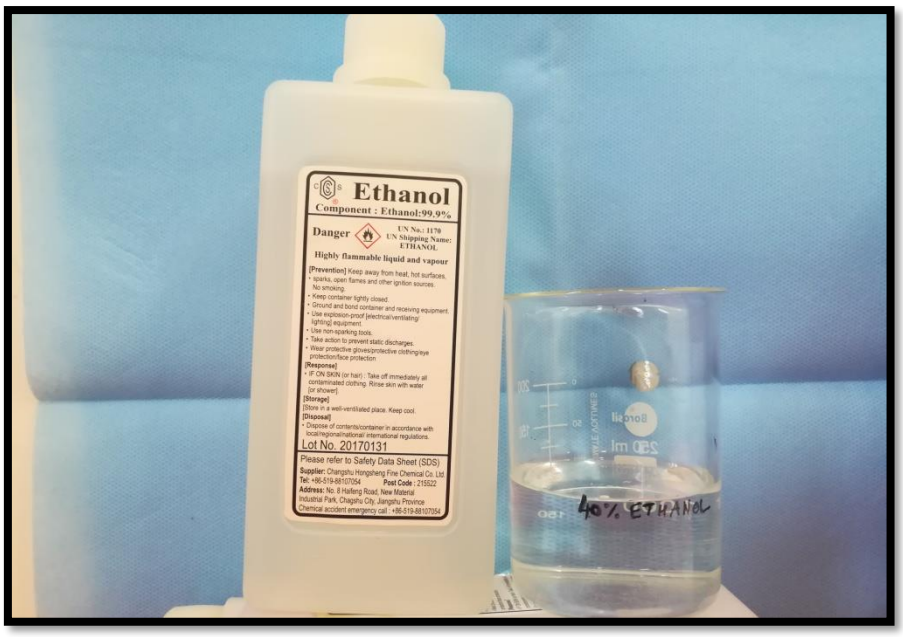


Fig 16: After diluting the 99.9% ethanol to 40% concentration in an individual beaker as Group C.

Fig 17: After diluting the 99.9% ethanol to 50% concentration in an individual beaker as Group D.

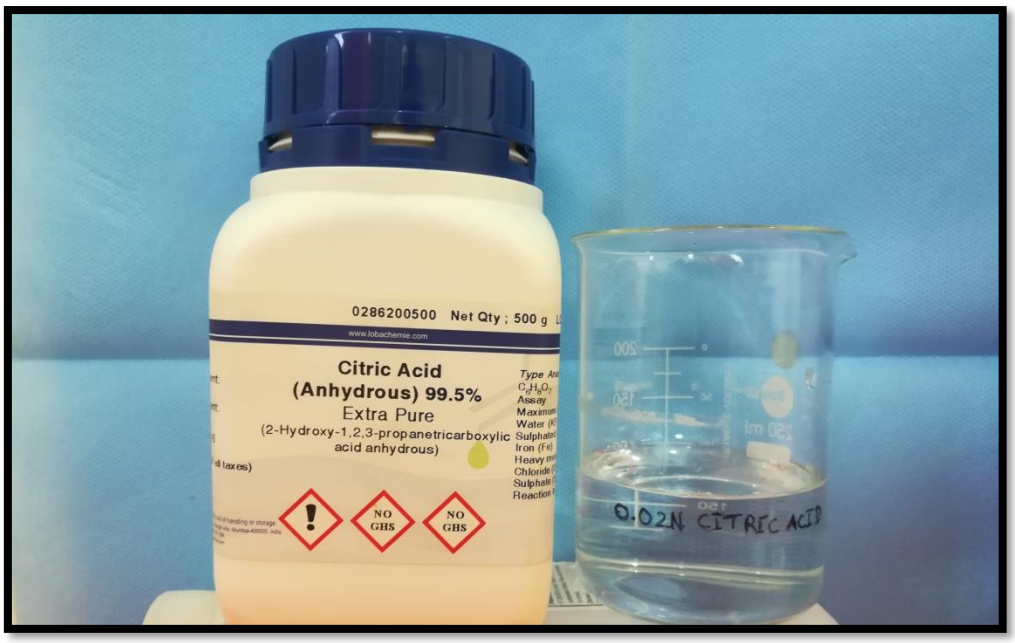


Fig 18: After diluting the 99.5% citric acid to 0.02 N citric acid in an individual beaker as Group E.

Fig 19: the sample is conditioned with the testing solutions (20% ethanol , 40% ethanol , 50% ethanol , 0.02 N citric acid)

Fig20: Sample under three point bending test (universal testing machine).

RESULTS

RESULTS

This study aimed at evaluating the changes in flexural strength of the denture base resins after exposure to the stimulating agents in food such as ethanol in three concentrations (20%, 40%& 50%) and citric acid (0.02N) for a period of 7 days. The flexural strength was then measured with the help of universal testing machine (Zwick Rowell, Germany) and recorded values were subjected to statistical analysis by using IBM SPSS (Statistical package for social sciences) Statistics for Windows, version 20.0,Armonk, NY:IBM Corp.

Table 3

Measurement of flexural strength by conditioning the samples in water

Group A (control group) for a week (7 days)

GROUP A	**Standard Force** $S_{M(N)}$	**Deformation rate** $r_{max(\%)}$
Specimen 1	151.7093	5.683286
Specimen 2	131.6886	4.374316
Specimen 3	113.7643	4.7802
Specimen 4	118.9585	5.672836
Specimen 5	120.6707	4.885114
Specimen 6	100.8277	4.486809
Specimen 7	120.7270	4.905114
Specimen 8	110.4123	4.487289
Specimen 9	149.7093	5.374316
Specimen 10	125.7024	4.897324

Table 3 shows that in Group A, based on the standard force maximum value is 151.7093 and minimum value is 100.8277; based on deformation rate 5.683286 is maximum value and 4.80651903 is the minimum value during the measurement of flexural strength.

Table 4

Measurement of flexural strength by conditioning the samples in Group- B (20 % ethanol)for a week (7 days)

GROUP B	**Standard Force** $S_{M(N)}$	**Deformation rate** $r_{max(\%)}$
Specimen 11	141.5085	4.368099
Specimen 12	114.5375	3.412868
Specimen 13	113.2671	5.034709
Specimen 14	162.6245	7.492003
Specimen 15	113.2671	5.034709
Specimen 16	109.9142	4.697189
Specimen 17	161.0546	7.442103
Specimen 18	105.4072	3.261444
Specimen 19	141.5085	4.368099
Specimen 20	114.5375	3.412868

Table 4 shows that in Group B(20 % ethanol) , based on the standard force the maximum value is 162.6245 and minimum value is 105.4072; based on deformation rate 7.492103 is maximum and 3.261444 is the minimum value during the measurement of flexural strength.

Table 5

Measurement of flexural strength by conditioning the samples in Group-C (40% ethanol)for a week (7 days)

GROUP C	**Standard Force $S_{M\,(N)}$**	**Deformation rate $r_{max(\%)}$**
Specimen 21	116.6668	3.676606
Specimen 22	124.7086	5.013470
Specimen 23	134.7841	6.805899
Specimen 24	148.9467	8.573927
Specimen 25	135.6615	5.401522
Specimen 26	126.3256	5.342188
Specimen 27	124.7132	5.69327
Specimen 28	119.4088	4.748045
Specimen 29	124.7143	5.59927
Specimen 30	132.9546	6.676606

Table 5 shows that in Group C(40 % ethanol) , based on the standard force maximum value is 148.9467 and minimum value is 116.6668; based on deformation rate 8.573927 is maximum and 3.676606 as the minimum value during the measurement of flexural strength.

Table 6

Measurement of flexural strength by conditioning the samples in Group D (50 % ethanol)for a week (7 days)

GROUP D	**Standard Force $S_{M\ (N)}$**	**Deformation rate $r_{max\ (\%)}$**
Specimen 31	127.9758	5.049767
Specimen 32	149.1998	6.01980
Specimen 33	153.6279	6.50339
Specimen 34	144.5327	6.032149
Specimen 35	135.8313	5.310130
Specimen 36	118.4306	4.201330
Specimen 37	153.2503	6.29996
Specimen 38	154.8080	7.019736
Specimen 39	127.9758	5.049767
Specimen 40	134.8313	5.206215

Table 6 shows that in Group D (50 % ethanol), based on the standard force the maximum value is 154.8080 and minimum value is 118.4306; based on deformation rate 7.019736 is maximum and 4.201330 as the minimum value during the measurement of flexural strength.

Table 7

Measurement of flexural strength by conditioning the samples in Group E (0.02 N- Citric acid) for a week (7 days)

GROUP **E**	**Standard Force** $S_{M\ (N)}$	**Deformation rate** $r_{max(\%)}$
Specimen 41	120.3515	4.116878
Specimen 42	128.9766	4.128781
Specimen 43	141.2419	5.57373
Specimen 44	130.4991	5.348434
Specimen 45	140.4986	5.872644
Specimen 46	140.2348	5.453611
Specimen 47	155.8523	6.528679
Specimen 48	128.9862	4.23415
Specimen 49	130.4982	5.29145
Specimen 50	140.4763	4.92351

Table 7 shows that in Group E(0.02 N citric acid), based on the standard force the maximum value is 155.8523 and minimum value is 120.3515; based on deformation

rate 6.528679 is maximum and 4.116878 as the minimum value during the measurement of flexural strength.

The Kolmogorov-Smirnov test and Shapiro-Wilk tests were evaluated to measure the flexural strength in which it showed insignificant difference due to equal data distribution. ANOVA and Post-Hoc analysis were applied to identify the difference in flexural strength between the groups.

Table 8:Tests of Normality to measure flexural strength

Groups		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	Df	Sig.
Group A	Sm	.346	10	.001	.809	10	.019
	rmax	.208	10	.200*	.872	10	.105
Group B	sm	.328	10	.003	.816	10	.023
	rmax	.326	10	.003	.821	10	.026
Group C	sm	.210	10	.200*	.884	10	.144
	rmax	.190	10	.200*	.943	10	.583
Group D	sm	.194	10	.200*	.913	10	.301
	rmax	.213	10	.200*	.877	10	.119
Group E	sm	.218	10	.196	.914	10	.308
	Rmax	.171	10	.200*	.923	10	.384

Table 8 : The results showed insignificance, so the data was under normal distribution and parametric analysis was used.

INTER GROUP COMPARISON:

One way ANOVA analysis:

Table 10

	Groups	Mean	S. D	n	F	p value
Standard force (Sm)	**Group A**	123.5	16.15	10	2.04	0.105
	Group B	127.7	21.83	10		
	Group C	129.6	11.92	10		
	Group D	141.5	12.21	10		
	Group E	133.7	10.84	10		
	Total	131.2	15.77	50		
Deformation rate (Rmax)	**Group A**	5.1	0.47	10	1.586	0.194
	Group B	5.1	1.35	10		
	Group C	6	1.29	10		
	Group D	5.4	0.96	10		
	Group E	5.1	0.69	10		
	Total	5.3	1.03	50		

Descriptive forms of various groups using one way analysis ANOVA

P value is insignificant in one way ANOVA test.

Table 10 shows descriptive forms of various groups using one way analysis of variance ANOVA in which the p- value of 0.105 was obtained for a mean standard force of131.2 and p-value of 0.194 was obtained for a mean standard force of 131.2. By analysing these two p-values, it clearly states that there is insignificant difference observed among the groups. For further analysis, Post-Hoc Tukey test was used to measure the flexural strength between the groups.

POST-HOC ANALYSIS:

Table 11:Descriptive analysis for various groups based on the standard force

Group vs Group	Mean difference	p value	standard error
Group A vs Group B	-4.2	0.538	6.77
Group A vs Group C	-6.1	0.372	
Group A vs Group D	-18.04	0.011	
Group A vs Group E	-10.19	0.139	
Group B vs Group C	-1.89	0.781	
Group B vs Group D	-13.83	0.047	
Group B vs Group E	-5.98	0.382	
Group C vs Group D	-11.93	0.085	
Group C vs Group E	-4.08	0.549	
Group D vs Group E	7.84	0.253	

In table 11, we observed that p-value = 6.77 showing insignificant difference among groups based on the standard force applied over the sample.

Table 12

Group vs Group	Mean difference	p value	standard error
Group A vs Group B	0.01	0.966	0.453698
Group A vs Group C	-0.91	**0.05***	
Group A vs Group D	-0.29	0.516	
Group A vs Group E	0.02	0.958	
Group B vs Group C	-0.93	**0.045***	
Group B vs Group D	-0.31	0.489	
Group B vs Group E	0.004	0.992	
Group C vs Group D	0.61	0.18	
Group C vs Group E	0.93	**0.044***	
Group Dvs Group E	0.32	0.482	

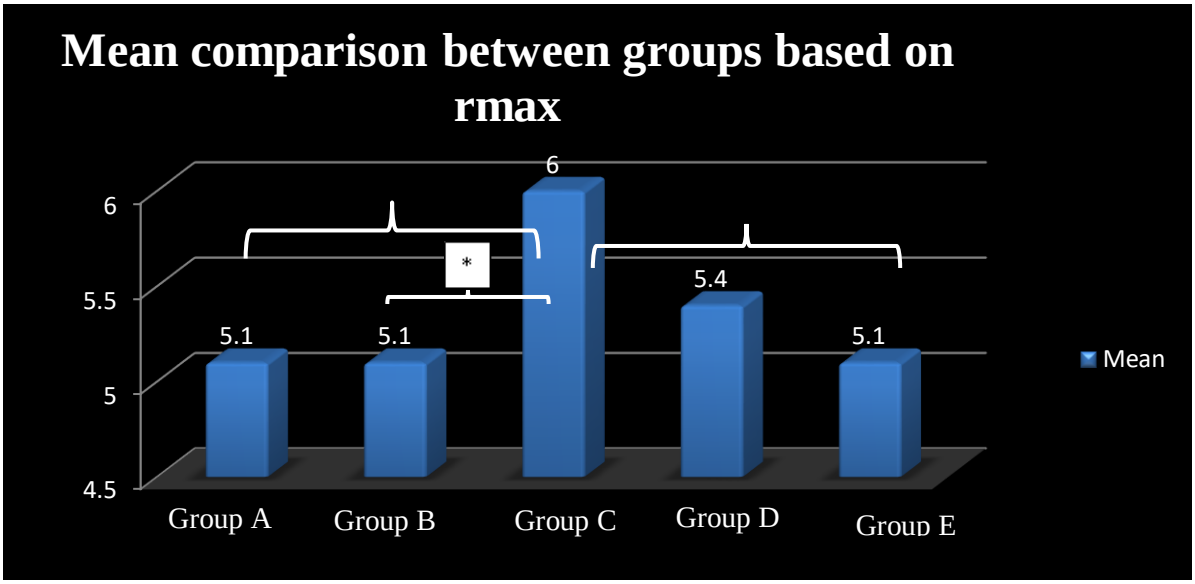
Descriptive analysis for various groups based on deformation rate (Rmax)

Post Hoc Tukey's test; P value <0.05* significant, p<0.01-highly significant.

Table 12 depicts descriptive analysis for various groups based on deformation rate (Rmax) by using post hoc test. In this, Group C (sample+ 40% ethanol) showed highest flexural strength change when compared with the Group A(control group) and

the difference was significant (p-value =0.05), whereas the Group B (sample+ 20% ethanol) showed significant difference when compared to Group C(p-value of 0.045) and finally Group E (sample + 0.02N citric acid) showed had significant difference when compared to Group C (sample + 40% ethanol) (p-value =0.044)

Graph: Mean comparison between groups based on deformation rate (Rmax)



The Graph shows mean comparison between the groups based on deformation rate. The difference is found to be significant (p-value-)0.05*(significant) between Group B (sample + 20% ethanol) , Group C(sample+40% ethanol) and Group E (sample+ 0.02N citric acid).

STATISTICAL INFERENCE:

By comparing the analysis, it is evident that based on the deformation rate of denture base resins exposed to stimulants in various groups there is significant difference among the groups when a standard force applied over the sample.

From the test of significance, it is evident that change in flexural strength was highest in Group C (sample+40% ethanol), followed by Group B (sample+20% citric acid) and followed by Group E (sample+ 0.02 N citric acid) whereas the least flexural strength was observed in Group D (sample+ 50% citric acid).

The highest significant difference was observed in Group C (sample+ 40% ethanol) (p-value = 0.05), followed by Group B (sample+ 20% ethanol) (p-value = 0.045) followed by Group E (sample+ 0.02N citric acid) (p-value= 0.044).Thus, there is rejection of null hypothesis $H_0$1 and acceptance of alternate hypothesis $H_1$1 .

DISCUSSION

DISCUSSION

This study has been carried out to determine the change in flexural strength of denture base resins when it interacts with ethanol in varying concentrations (20%, 40% & 50%) and citric acid (0.02N).The chemical agents used in this study have been chosen on the basis of guidelines published by Food and Drug Administration (FDA, 1976, USA) which is also known as a food simulators. Distilled water, Ethanol and Citric acid solutions are also considered as food simulators [12].Yap et al[12] and Yesilyurt et al[11] stated that, in the oral cavity acrylic resins have been exposed either intermittently or continuously to these chemical substances. Intermittent exposure happens while drinking or eating until we clean our teeth mechanically. On the other hand, continuous exposure happens when these agents are absorbed by debris like calculus or food particles from the restorations or bacterial putrefaction of debris [12, 34]. Thus, the Poly methyl methacrylate (PMMA) dentures in the oral cavity of alcoholic drinkers function in an acidic environment. In order to calculate the action of acidic environment on denture base resin with alcohol, initially we need to calculate the average duration of alcohol consumption so that average dose of alcohol consumed by the particular individual can be identified. Guler et al [41] have shown that a regular drinker consumes alcohol, approximately 3.2 doses on a daily basis and each dose lasts for 15 minutes. The 24 hour storage time simulates one month of consistent drinking. Rajee et al [39] found out that, 7 days immersion period represented7 months consumption of that beverage. Although this period may seem long due to the fact that the restorations only come into contact with foods and beverages for the duration of eating and drinking until teeth are cleansed but these chemical agents can attach around the margins under the denture and into porosities of poorly manipulated materials. Moreover, calculus or food particles may also serve

as reservoirs for these chemicals, leading to an increase in the exposure time for the restoration to the agents. This in vitro study had calculated for a period of 7 months by conditioning it for 7 days.Vlissidis and Prombonas [16] have reported that alcohol alters the useful properties in two different ways. First way it creates stress crazing in dentures that consequently reduces the static and dynamic strength of the denture base material. The second way, alcohol has corrosive effects on the denture surface which may speed up the fatigue processes within the denture material, causing premature fracture.Yap et al [12] have correlated the destruction mechanism of alcohol by softening and damaging the polymer matrix which in turn removes the matrix partially from the surface. This particle removes the matrix which would lead to degradation of the filler-matrix interface and consequently impairing the mechanical properties. Accordingly it may be advocated that alcoholic beverages would possibly compromise the functional longevity of denture. So, it's the duty of the clinician to inform their patients about the possible effects of alcohol on the denture, particularly about longevity of the denture. Not only ethanol has possible effects, even citric acid which is a weak acid, which significantly decreases bond strength of soft liner and denture base. Thus, the chemical softening may show change in the physico-mechanical properties of particular material especially its hardness and flexural strength. The latter includes diametric tensile strength, fracture toughness, hardness & wear. As the greatest change in the hardness had been shown to occur within the first 7 days [22]. In this study, when comparing with control group and other groups, the flexural strength has been decreased significantly in ethanol of 20% and 40% (p-value-0.045).The similar study conducted by Rajee et al[39] stated that ethanol and citric acid had decreased flexural strength when compared to control group(p value <0.05).

Vlissidis[16] reported that over 40 % alcohol in alcoholic drinks generate significant effects, it was shown that beverages with alcohol content as low as 25% could compromise longevity of resin based materials and thus it showed decrease in flexural strength with a p-value of 0.01. In this study, we observed that 40% ethanol showed highest significant difference when compared with other groups such as water (p-value-0.05) and 20% ethanol (p-value-0.045).

Yesilyurt et al[11] did a study in composites with ethanol where he identified that organic solutions may damage the resin matrix and even water and citric acid can damage the organic fillers. Therefore organic solutions can decrease the strength of the material especially the flexural strength.

Azevedo et al[1] did a study based on immersion of denture base resin in water where he observed that water led to reduction in the hardness of the resin samples. Similarly Lee et al[28] showed that both water and residual monomer molecules in denture base resin act as plasticizers, thus affecting the strength of polymerized resins .Hence he concluded that the reduction in hardness of resin materials during first two days of immersion in water is due to more plasticizing effect of water intake than the released residual monomer molecules. However, they both proved that the flexural strength of the denture base resins was not affected when it is stored in water. Thus in our study, also we observed that there was least significant changes in control group when compared with other groups of ethanol especially (20% & 40%).

Citric acid , which is considered as a weak intra oral acid has decreased the flexural strength of the denture base resins. It causes silane hydrolysis and micro crack formation by altering the mechanical properties in composite resins[19]. Moreover, it has been showed the harmful effect of weak intraoral acids (citric acid) on inorganic

fillers. Thus, the studies done by Rajaee et al[39] had shown changes in flexural strength due to action of citric acid but further studies has to be carried out to check the hardness effect by citric acid.

In this study, Group E (citric acid) showed significant difference (p-value-0.044) when compared to Group C (40% ethanol) and Group B (20 % ethanol) with a change in flexural strength of denture base resins.In general, the changes taken place in denture base resins has been observed by means of properties both mechanically and physically.

Chemistry of monomer resins:

The water has a plasticizing effect, which shows changes in resin matrix by altering the hardness of the restoration [23] whereas the ethanol and citric acid shows destructive mechanism by the release of residual monomer and hydrolysis in resin matrix.

The extent of polymerization of the polymer matrix:

The polymerization shrinkage and diffusion of moisture may lead to the initiation and propagation of micro cracks in the resin matrix of composites .The similar mechanism has taken place in denture base resins, by diffusion of chemical agents which subsequently undergo degradation by breaking the bond between resin matrixes[12].

Contact surface of resin:

The contact surface is considered as a contributing factor for the interaction between the food stimulating agents and denture base resins. The food stimulating agents directly acts on the interface between the bond between resin and matrix which

undergoes degradation of the resin matrix and decreases the longevity of the denture base resins [28].

Thus, in vitro study could provide information on materials, based on test results. However, further investigations are needed for longer periods with clinical studies to assess whether other physical or chemical properties are influenced by the processing procedure or time involved.

Limitations of the study:

This study has certain limitations like

1. As, it is an in vitro study it does not simulate the changes taken place in oral environment.

2. This study can be further investigated by identifying the changes taken place chemically in denture base resins which alters the properties. Thus, nano technology will be more appropriate when compared to other modes of investigations.

3. This study has to be correlated with the socio-economic status of an individual if it is undergoing an in-vivo investigations.

SUMMARY

SUMMARY

An in-vitro study was done to evaluate the changes in flexural strength of denture base resins using ethanol of three different concentrations (20%, 40% and 50%) and citric acid (0.02 N).In 50 acrylic samples, 10 acrylic samples of each group were conditioned with ethanol of 20% concentration (Group B), 40% concentration (Group C), 50% concentration (Group D) and 0.02 N citric acid (Group E). These samples were conditioned for a week and it was subjected to three point bending test to determine the flexural strength. The data were obtained and statistically evaluated with one way ANOVA and Post-hoc analysis.

In one way ANOVA test; there was insignificant difference among the groups. In Post-hoc analysis, there was significant difference between Group A (control group) and Group C (40% ethanol) of p-value - 0.05; between Group B (20% ethanol) and Group C (40% ethanol) of p-value - 0.045; between Group C (40% ethanol) and Group E (0.02N citric acid) of p-value - 0.044.

The highest changes were seen in Group C (40% ethanol) followed by Group B (20% ethanol), Group E (0.02 N citric acid) and least changes were seen in Group D (50% ethanol).

CONCLUSION

CONCLUSION

The present study was undertaken to evaluate the changes in the flexural strength of Poly methyl methacrylate resin with food stimulating agents namely 20%, 40% and 50% concentration of ethanol and 0.02 N citric acid.

The following conclusions were drawn from this study:

The changes in the flexural strength of Poly methyl methacrylate resin seen in Group C (40% ethanol) showed more significant changes when compared to Group B (20% ethanol) , Group E (0.02 N citric acid) and Group D (50% ethanol).

CONCLUSION

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GLOSSARY

1. PMMA	Poly methyl methacrylate
2. BISGMA	Bisphenol A-glycidyl methacrylate
3. TEGDMA	Tri-ethylene-glycol-dimethacrylate
4. SEM	Scanning Electron Microscope
5. FTIR	Fourier Transform Infrared Spectroscopy
6. ASTM	American Standard Test Methods
7. FDA	Food and Drug Administration
8. UTM	Universal Testing Machine

Urkund Analysis Result

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